REMARKS

Claims 1-10 are pending in the present application. The rejections set forth in the office action are respectfully traversed below.

Claims 1-3 and 9 stand rejected under 35 U.S.C. §102(b) as being anticipated by Yoo.

Claims 1, 3 and 5-7 stand rejected under 35 U.S.C. §102(b) as being anticipated by Kirchner et al.

Claims 4 and 8 stand rejected under 35 U.S.C. §102(b) as being anticipated by or in the alternative under 35 U.S.C. §103(a) as being unpatentable over Kirchner et al.

It is submitted that nothing in the prior art, either alone or in combination, teaches or suggests all the features recited in the present claimed invention. For instance, nothing in the cited prior art teaches or suggests at least the claimed feature of the metal oxide film formed at an interface to a surface of the semiconductor layer, the metal oxide film being an element different from the element constituting the compound semiconductor layer and having a free energy of formation larger than the absolute value of a free energy of formation of an oxide of the element constituting the semiconductor layer.

One primary aspect of the present invention is to provide a compound-semiconductor triode device having stabilized threshold characteristics by suppressing the diffusion of a metal element such as Ti into the compound semiconductor channel layer.

In order to achieve this object, the present invention provides a metal oxide film between the compound semiconductor layer forming the channel and the Schottky gate electrode. In the present invention, the chemical stability of the metal oxide film is important. When the metal oxide film is chemically unstable (and thus having a small free energy of formation), the metal oxide

constituting the metal oxide film would undergo decomposition into the metal element and oxygen, and the metal element thus formed would penetrate into the compound semiconductor channel layer. In order to ensure that such a decomposition does not take place, it is necessary to chose the material of the metal oxide such that the free energy of formation (Gibbs free energy of formation) of the metal oxide is smaller (larger in terms of absolute value) than the free energy of formation of the oxide of the element constituting the compound semiconductor layer. As per attached, TiO_2 used for the metal oxide film has a Gibbs free energy of formation of -888.8kJ/mol, which is larger in terms of absolute value of the Gibbs free energy of formation of $1/2Ga_2O_3$ ($GaO_{3/2}$) of -499.15kJ/mol (=-998.3/2kJ/mol) or the Gibbs free energy of formation of $1/2As_2O_5$ ($AsO_{5/2}$) of -391.15kJ/mol (=-782.3kJ/mol), assuming that GaAs is used for the compound semiconductor substrate.

Similarly, ZrO_2 or HfO_2 can be used also for the metal oxide film of the present invention as can be seen in the attached Table.

Yoo discloses a ferroelectric memory device having a ferroelectric storage film in a gate structure in the state that the ferroelectric storage film is sandwiched by upper and lower electrodes, wherein the reference teaches the use of a gate insulation film of $PbTiO_3$, $SrTiO_3$, $KTaO_3$ and the like.

This reference, however, is silent about the use of a compound semiconductor substrate or a compound semiconductor channel layer. The reference only teaches the use of a silicon substrate or silicon channel layer. See column 1, line 49, column 2, lines 30 and 34, and the like. Thus, the reference fails to teach all the features recited in the present claimed invention. Further, there is no motivation to modify the teaching of **Yoo** to provide a metal oxide film on a compound semiconductor layer as recited in the present claimed invention.

Kirchner teaches a compound semiconductor triode having a Ga oxide film between the n-type FaAs channel layer and the gate electrode. Thus, according to **Kirchner**, the metal oxide film is formed of the oxide of the compound semiconductor material forming the channel layer. In such a structure there is a possibility that oxidation of the GaAs substrate may proceed as a result of growth of the Ga oxide film. Accordingly, there arises a problem of unstability of threshold characteristics.

According to the present invention, the foregoing problem found in the device disclosed in **Kirchner** is successfully avoided by using a chemically stable metal oxide for the metal oxide film as set forth in amended claim 1. For at least these reasons, the present claimed invention patentably distinguishes over the prior art.

New claim 10 was also added by this Amendment. New claim 10 clearly recites that the channel layer is a compound semiconductor layer, the gate electrode has a stacked structure of Ti, Pt and Au and that the intermediate layer is formed of TiO_2. These features are not disclosed in any of the cited references.

In view of the aforementioned amendments and accompanying remarks, the claims are believed to be in condition for allowance, which action, at an early date, is requested.

Minor typographical errors in the specification were also corrected by this Amendment. A Request for Approval of Drawing Changes is concurrently submitted herewith, also to correct apparent typographical errors.

If, for any reason, it is felt that this application is not now in condition for allowance, the Examiner is requested to contact Applicants undersigned attorney at the telephone number indicated below to arrange for an interview to expedite the disposition of this case.

Attached hereto is a marked-up version of the changes made to claim 1 by the current amendment. The attached page is captioned "**Version with markings to show changes made**."

In the event that this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. Please charge any fees for such an extension of time and any other fees which may be due with respect to this paper, to Deposit Account No. 01-2340.

Respectfully Submitted,

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PATENT TRADEMARK OFFICE

Enclosures:
Table
Version with markings to show changes made
Request for Approval of Drawing Changes

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IN THE SPECIFICATION:

The paragraph beginning at page 14, line 7, has been replaced with the following, rewritten paragraph:

-- In the structure of FIG. [8A] 9A, a gate electrode **63** of WSi is formed on the TiO_2 film **62** with a thickness or height of about 300nm.--

The paragraph beginning at page 14, line 10 has been replaced with the following, rewritten paragraph:

-- Next, in the next step of FIG. [8B] 9B, an ion implantation process of Si^+ is conducted into the GaAs substrate **61** while using the gate electrode **63** as a self-alignment mask, and n^--type LDD regions **61B** and **61C** are formed in the substrate **61** at both lateral sided of the WSi gate electrode **63**.--

The paragraph beginning at page 14, line 16, has been replaced with the following, rewritten paragraph:

-- Next, in step of FIG. [8B] 9B, and SiN film is deposited on the GaAs substrate **61** by plasma CVD process such that the SiN film covers the WSi gate electrode **63**, and side wall insulation films **63A** and **63B** are formed on both lateral side walls of the gate electrode **63** as a result of anisotropic etching process applied of the SiN film such that the etching proceeds generally perpendicular to the principal surface of the substrate **61**. --

The paragraph beginning at page 14, line 25 has been replaced with the following, rewritten paragraph:

-- In the step of FIG. [8B] <u>9B</u>, a further ion implantation process of Si^+ is conducted under an acceleration voltage of 50keV with a dose of 5 x $10cm^{-2}$ while using WSi gate electrode **63** and the side wall insulation films **63A** and **63B** as a self-aligned mask, and n^+-type diffusion regions **61D** and **61E** are formed in the GaAs substrate **61** at outer sides of the LDD regions **61B** and **61C**, respectively. --

<u>IN THE CLAIMS:</u>

Please amend Claim 1, as follows:

1. (Amended) A semiconductor triode, comprising:

a <u>compound</u> semiconductor layer including a channel layer;

a first ohmic electrode supplying carriers into said channel layer;

a second ohmic electrode collecting carriers from said channel layer; and

a gate electrode controlling a flow of said carriers through said channel layer from said first ohmic electrode to said second ohmic electrode,

said gate electrode including an insulating metal oxide film formed at an interface to a surface of said semiconductor layer<u>,</u>

<u>said metal oxide film being formed of a metal oxide of an element excluding an element constituting said semiconductor layer, said metal oxide having a free energy of formation larger than the absolute value of a free energy of formation of an oxide of an element constituting said semiconductor layer</u>.

Attachment

生成自由エネルギー
Standard molar Gibbs energy of formation at 298.15K
ΔG[kJ/mol)

Ti_3O_5	−2317.4
Ta_2O_5	−1911.2
Al_2O_3	−1582.3
$BaTiO_3$	−1572
T_2O_3	−1434.2
HfO_2	−1088.2
ZrO_2	−1042.8
Ga_2O_3	−998.3
TiO_2	−888.8
In_2O_3	−830.7
As_2O_5	−782.3
Co_3O_4	−774
MoO_3	−668
MoO_2	−533
TiO	−495
CoO	−214.2
As_2O_3	−168.6

TABLE